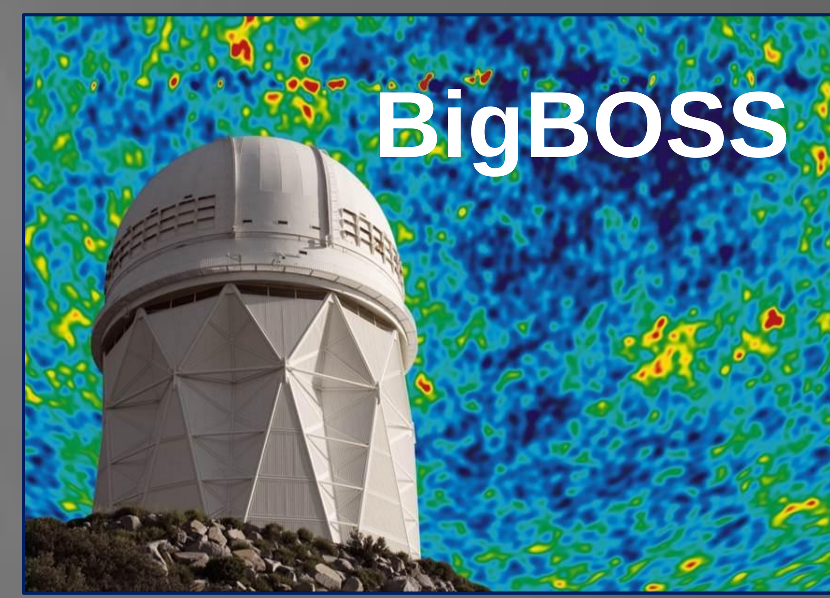
BigBOSS Optical System

Michael Sholl and the BigBOSS Collaboration

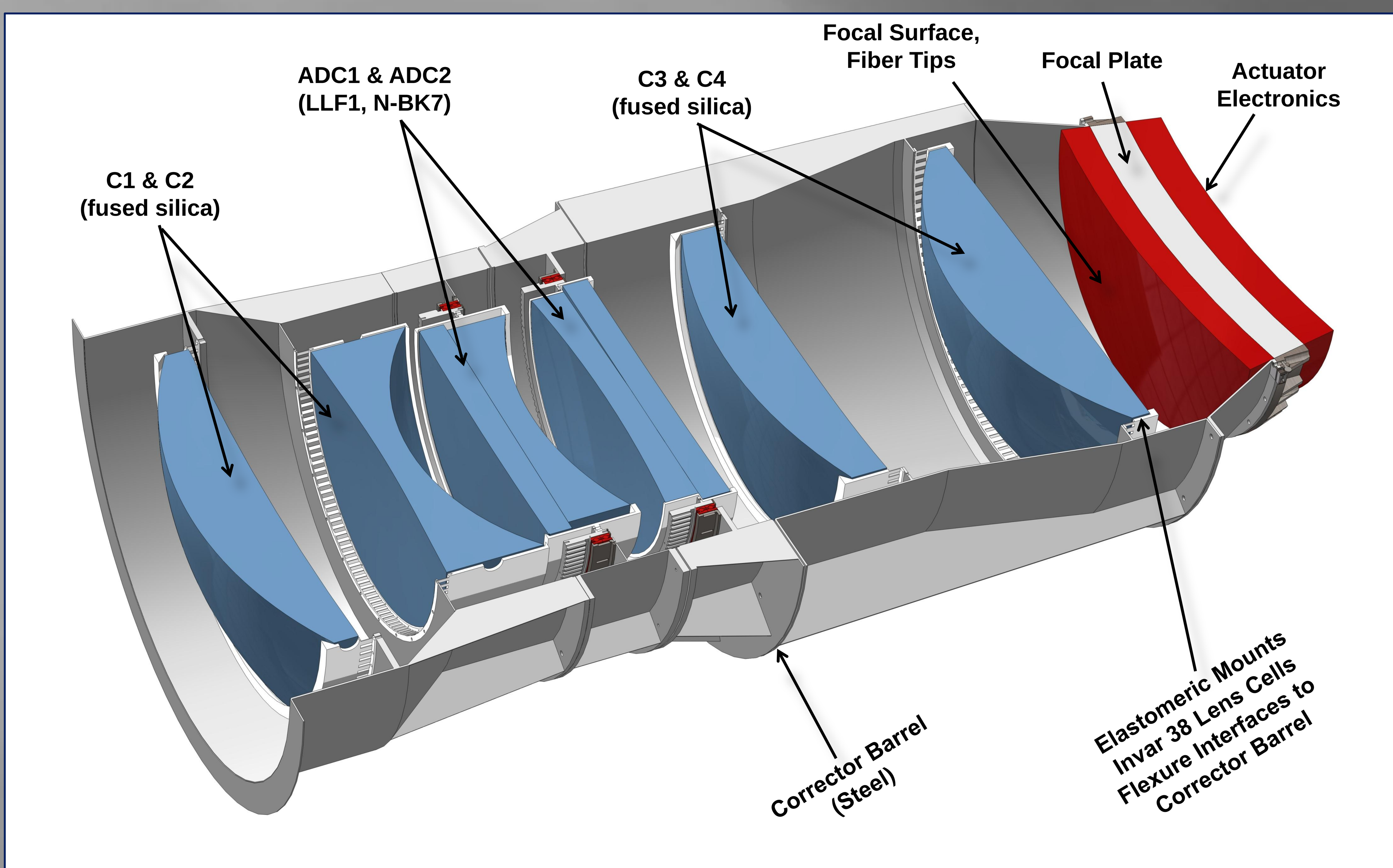
BigBOSS is a proposed ground-based dark energy experiment designed to study baryon acoustic oscillations (BAO) and the growth of large scale structure through a 14,000 square degree survey of emission line galaxies, luminous red galaxies and quasi-stellar objects. The project involves design, construction and installation of a new widefield optical corrector for the Mayall 4m telescope. The corrector magnifies the f/2.81 prime focus to f/4.5 over a circular field of view of three degrees.

A prism-based atmospheric dispersion compensator is included in the design, to allow broadband spectroscopy over a range of angles up to 60 degrees from zenith. A robotically positioned 5000 fiber system directs galaxy light to a remote array of 10 spectrometers, each with three channels. Optical requirements, baseline design, alignment, atmospheric dispersion correction and system engineering throughput budgets are discussed.



BigBOSS: Enabling Widefield Cosmology on the Mayall Telescope

BigBOSS 3˚ Widefield Corrector



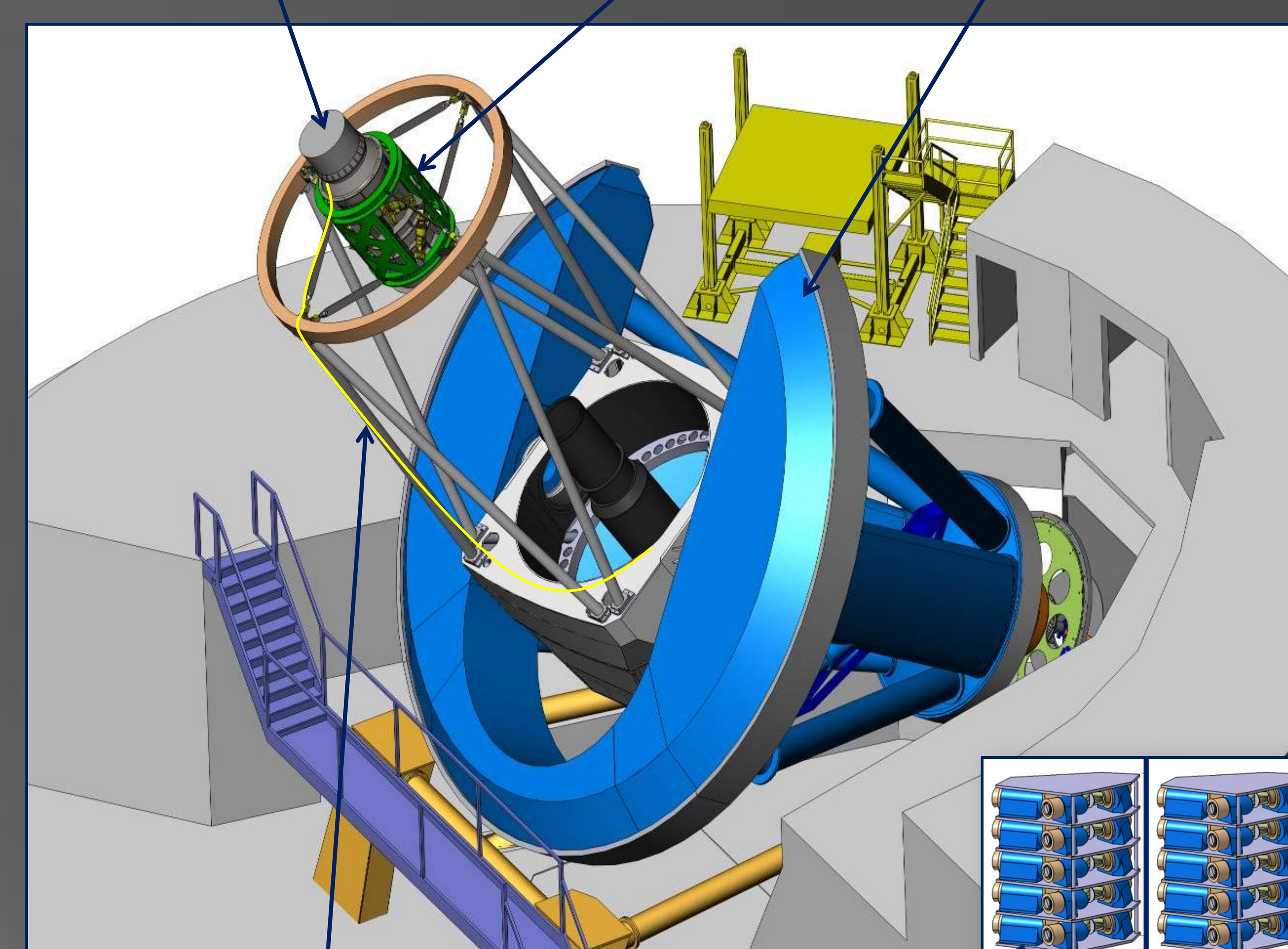
The BigBOSS widefield corrector produces a 3˚ image of the sky on a spherical focal surface. Fiber positioner robots position 5000 fibers on galaxy positions for a given telescope pointing. Individual lenses are mounted athermally to low-expansion alloy rings. The current pre-conceptual baseline design has six groups, four of which are fused silica, and two of which are LLF1 & N-BK7. Magnification is performed primarily by the fused silica groups, and color and atmospheric dispersion correction by the LLF1 elements.

BigBOSS Installation at Mayall 4m Telescope

5000 robotically positioned fibers

3˚ Prime Focus Corrector
(See P. Perry, Thermo-Mechanical Design of the BigBOSS Prime Focus Corrector)

Existing Mayall truss, M1 & equatorial mount
(See R. Besuner, Integration of the BigBOSS Instrument with the Mayall 4m Telescope)



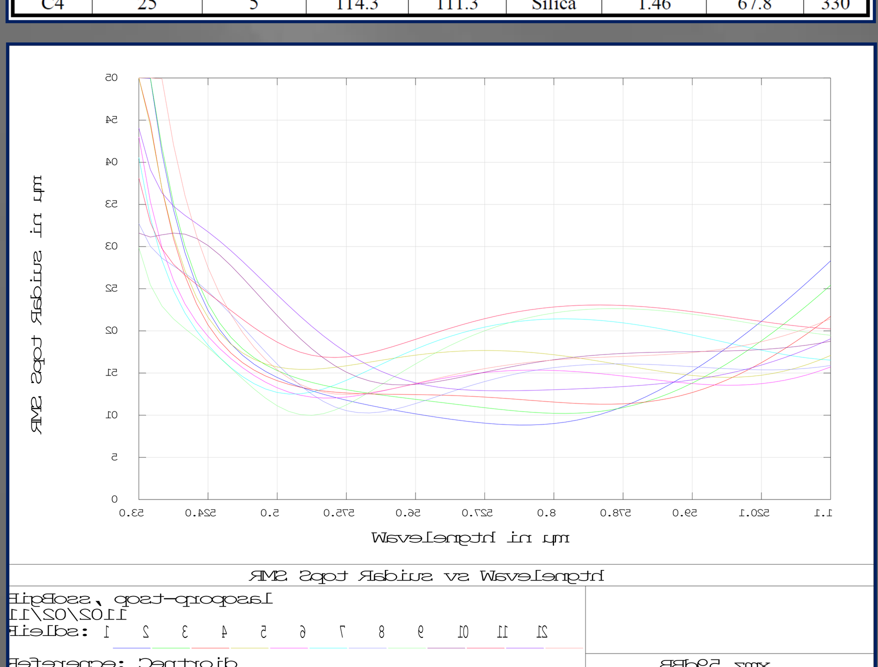
Fiber system (yellow)
(See J. Edelstein, BigBOSS Fiber System)

Spectrometers (10 × 3-arm)
(See P-H. Carton, A Spectrograph for BigBOSS)

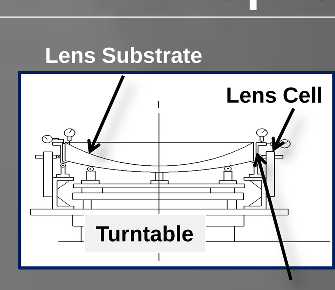
Requirements and Baseline Performance

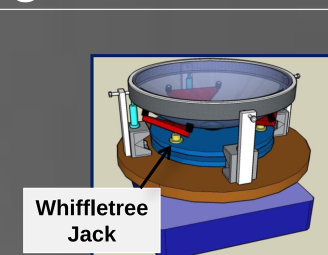
Parameter	Requirement/Specification	Notes
Telescope	Mayall 4m, 3.797m aperture, f/2.8, 21.34m ROC, Conic constant: -1.098	Aluminum coating on M1
Final f/number	f/4.5 (17.1m effective focal length)	1.6× magnification
Field of View	±1.5°	
Spectrometer channels and bands	UV: 360-660nm (R > 1500) VIS: 620-840nm (R > 4000) NIR: 800–980nm (R > 4000)	
Geometric blur:	<0.5 arcsec FWHM, field weighted, 17 points.	Design residual error
Chief Ray Deviation from normal to focal surface	≤0.5°, field weighted, 17 field points	
Elevation range	0-60° from zenith	Will require ADC

Lens Group	Center Thickness (cm)	Edge Thickness (cm)	Physical Aperture Diameter (cm)	Clear Aperture Diameter (cm)	Material	Index	Abbe number ν_A	Mass (kg)
C1	20	6.2	112.2	109.2	Silica	1.46	67.8	276
C2	7	28.3	90.0	87.0	Silica	1.46	67.8	241
ADC1	14	24.1	85.0	82.0	LLF1/ N-BK7	1.55/1.51	45.8/64.2	227
ADC2	14	17.2	90.0	87.0	LLF1/ N-BK7	1.55/1.51	45.8/64.2	222
C3	18.5	9.8	94.4	97.4	Silica	1.46	67.8	233
C4	25	5	114.3	111.3	Silica	1.46	67.8	330

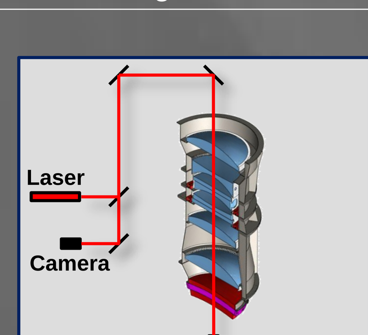


Optical Alignment





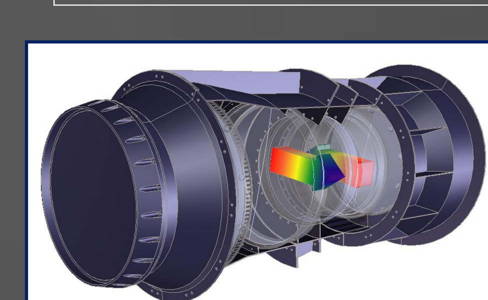
University College London (UCL) recently completed fabrication and alignment of the DECAM corrector (shown) for the Blanco 4m telescope. UCL will procure BigBOSS optics and mount and align individual lens elements in low-expansion cells on a rotary turntable. Figure credit: P. Doel.

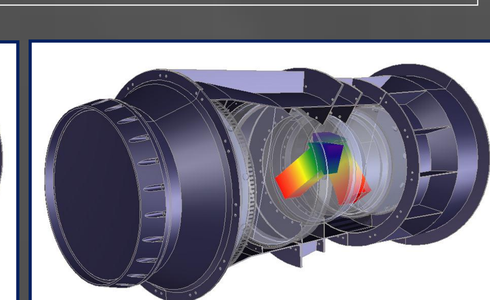


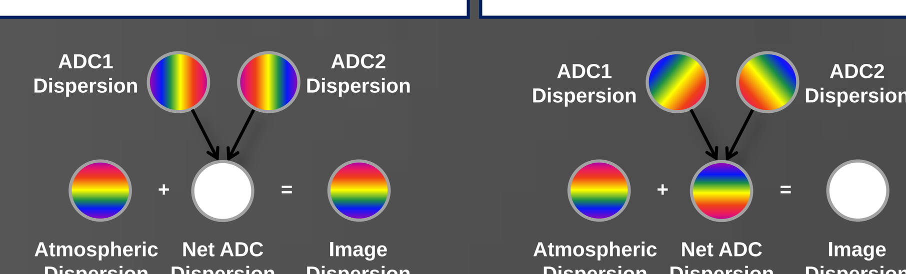
Lens cells are mounted in the corrector barrel and alignment verified with the laser turntable apparatus. DECAM body shown on turntable in UCL laboratory (P. Doel).

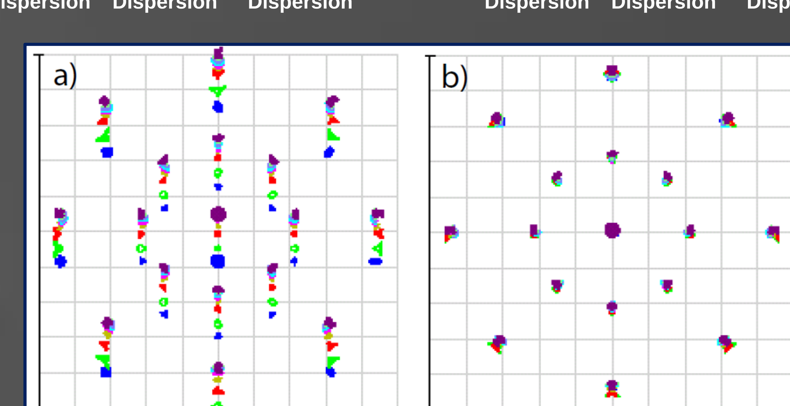
Atmospheric Dispersion Compensator

Atmospheric dispersion is removed (to first order) by a pair of rotary zero deviation prisms. Dispersions of the individual prisms are shown below with arrows. Prisms may be clocked to produce dispersion opposite that of the atmosphere at a given observation elevation (See Wynne, 1984 and Liang, 2004 & 2009).



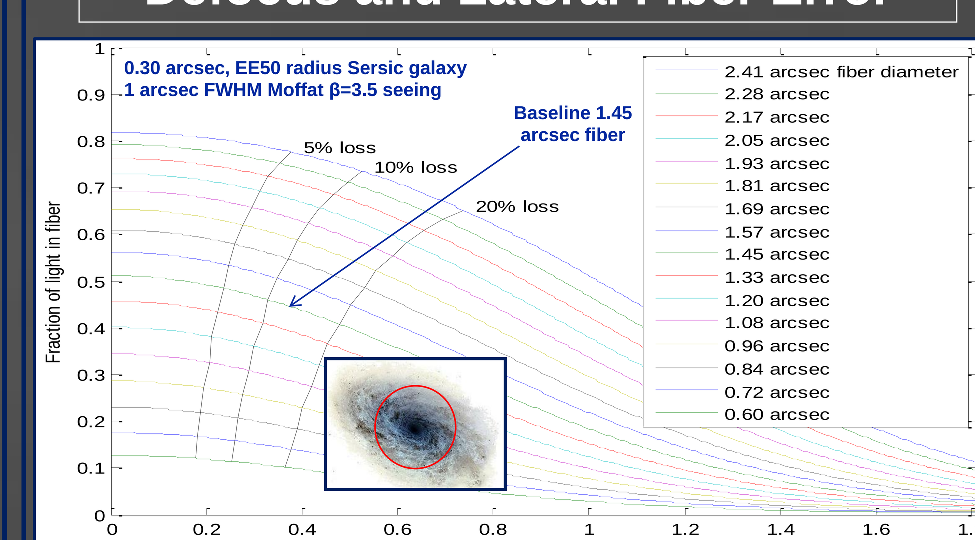




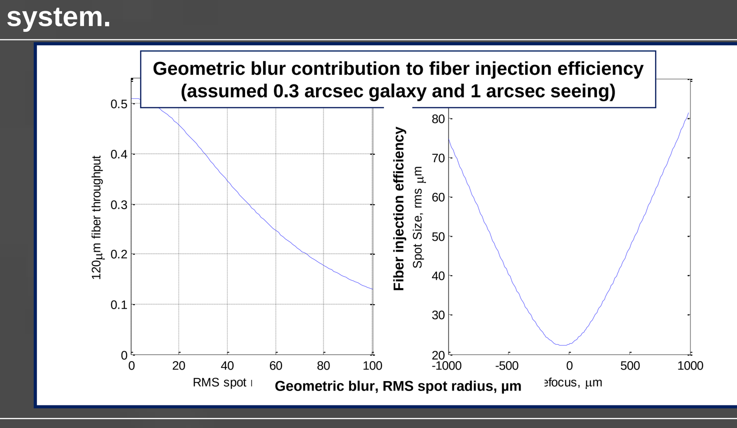


Exaggerated (magnified) chromatic aberration (3 arcsec) shown. Full scale is 0.95m.	Compensated with ADC

Defocus and Lateral Fiber Error



A main element of BigBOSS Systems Engineering is maintenance of a system throughput budget. Defocus errors and allowances for lateral misalignment of the fibers relative to the focal plane image of a target galaxy define the performance requirements of the system.



Throughput (below left) and corresponding lateral misalignment allowances (below right) show a subset of the throughput budget, and corresponding performance requirements.

Lateral and tilt errors	**0.888**	
Astrometry errors	0.964	16um (200mas)
Telescope guiding/tracking errors	0.991	8um (100mas)
Fiber view camera error	0.997	5um
Thermal distortion of focal plate (lateral)	0.998	4um (Al, 0.4C max delta T during observation)
Patrol disk control discretization	0.998	4um
Step inhomogeneity	0.999	3um
2nd-Cycle Absolute Error	0.997	5um
Fiber Vibration	1.000	Mayall accel. Testing

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